Clinical Preconditions and Treatment Modality: Effects on Pulp Surgery Outcome

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Background: **The purpose of this research was to evaluate the factors affecting the outcome of localized laser pulp surgery in the canine model.**
Study Design/Materials and Methods: **Pulpal exposures 2 mm and 5 mm in diameter were prepared in eight healthy teeth in each of five dogs. The total of 40 teeth were left open to infection from the oral cavity for 3 hours or 72 hours; 2–3 mm of surface pulpal tissue were then removed using a fresh diamond bur or a CO_2 laser emitting @ 9.3 μm, at 3.5 W average power in the Superpulse mode. Teeth were monitored clinically and radiographically by one blinded, pre-standardized clinician for 3 months.**
Results: **Chi-square test and Fisher's Exact test (2-tail) results associated laser treatment with significantly better clinical and radiographic outcome ($P < 0.001$). Using regression analysis, duration of pulpal exposure to contamination by the oral environment was identified as primary determinant for treatment outcome within the laser-treated and control groups ($P = 0.0018$).**
Conclusion: **Clinical preconditions significantly affect the outcome of pulp surgery treatments. Lasers Surg. Med. 22:25–29, 1998.**

Key words: calcium hydroxide; CO_2 laser; laser treatment; pulpotomy

INTRODUCTION

Conventional pulp treatments used in mature adult teeth include pulp capping or root canal therapy. Whether the pulp capping is indirect or direct, the outcome of the treatment is often unpredictable, with reported success rates rangingfrom 44–97% [1]. The success rate for full root canal treatment has been reported to be 78–90% [2,3], depending on factors such as the pathologies treated, tooth anatomy, and follow-up duration. In immature permanent teeth, the choice for endodontic treatment is pulpotomy with subsequent dressing of calcium hydroxide. However, this may ultimately result in internal tooth resorption [4]. In primary teeth, pulpotomy procedures are still widely used in conjunction with formocresol, despite concerns over its irritancy [5], toxicity, and mutagenicity [6–8].

Clinicians and patients alike would prefer to avoid unpredictable pulp capping or pulpotomy procedures as well as tooth devitalization and root canal therapy. However, we do not possess an adequate clinical capability for performing localized pulp surgery (e.g., pulpotomy) and wound dressing to allow predictable pulpal healing and longterm survival.

The preconditions for localized pulp surgery include atraumatic removal of compromised

Contract grant sponsor: DOE; Contract grant number: DE903-91ER 61227; Contract grant sponsor: ONR; Contract grant number: N00014-90-0-0029; Contract grant sponsor: NIH; Contract grant number: RR01192.

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Accepted 15 August 1997

pulpal tissues [9], hemostasis and minimal clot formation [10,11], and bacterial elimination [4]. These preconditions can be achieved using the CO_2 laser emitting at 10.6 μm at appropriate parameters. Nontraumatic soft tissue surgery using this device has been documented for a wide range of clinical applications for more than 30 years (12–17). The CO_2 laser is appropriate for such purposes because it emits an infrared beam that is readily absorbed by the water in soft tissue [16,18]. Recent research has demonstrated that laser effects in soft tissue are identical at wavelengths of 10.6 and 9.3 μm [19]. The absorbed energy causes vaporization of the intra- and extracellular fluid and destruction of cell membranes [12]. Tissue penetration by the laser beam is minimal and laser effects remain superficial [18,19]. Because the laser handpiece is used in the noncontact mode, it has no mechanical contact with the tissue, and trauma to the residual tissues is avoided [13,16,17].

Laser irradiation at this wavelength consistently achieves rapid and effective hemostasis and minimal clot formation in blood vessels up to 0.5 mm in diameter [20,21]. Many authors report effective wound sterilization during soft tissue surgery with this laser [12,22,23]. The CO_2 laser irradiation can achieve sterilization and hemostatis in an open pulp wound [23]. Many authors associate CO_2 laser soft tissue surgery with reduced swelling, oedema, and pain [12,13,20,24, 25]. Pulpal exposure to CO_2 laser irradiation has been linked with reparative dentin formation [23]. Thus the CO_2 laser is able to fulfill the prerequisites for successful localized laser pulp surgery. Preliminary in vivo studies have demonstrated good clinical outcome in minimally exposed and infected pulps after localized CO_2 laser pulp surgery [26]. However, the effect of clinical preconditions on treatment success has not been addressed at this time.

The objective of this research was to determine the effects of exposure size and duration of wound contamination on the outcome of localized laser surgery of infected pulps in dogs. These results were compared with those achieved using a sterile diamond bur.

MATERIALS AND METHODS

Treatment

These studies were performed in five healthy, adult beagle dogs ~12 months in age. The protocol was reviewed and approved by the appropriate animal care committees. Animals were premedicated with i.m. Promazine Maleate (0.1–0.25 mg/kg) prior to the induction and maintenance of anesthesia using i.v. pentobarbital sodium (30 mg/kg). Once full anesthesia was achieved, preoperative standardized periapical radiographs were taken. Forty healthy teeth were included in this investigation: left and right upper and lower third premolars and first molars. In each of the five dogs, four teeth received laser treatment and four served as controls. Treatment allocation within each dog was randomized; the teeth were allocated to one of the eight groups (Table 1). In each dog, 2 mm exposures were prepared in four teeth and 5 mm exposures in the other four teeth by using the high speed dental drill, a round diamond bur, and sterile saline coolant. Then, still under sterile saline cooling, a fresh diamond bur rotating at a slow speed (<5,000 rpm) was used to expose the pulp. Two of the 2 mm and two of the 5 mm exposures were left open to contamination from the oral cavity for 3 hours; the remaining two 2 mm and two 5 mm exposures were left open for 72 hours. In one tooth in each group, pulpal tissues were ablated 2–3 mm beyond the exposure site using a CO_2 laser emitting at 9.3 μm (Duolase™, Medical Optics, Carlsbad, CA). Average irradiation duration measured approximately three bursts of 1 second each. In the other tooth in each group, pulpal tissues were excised using a fresh sterile diamond bur. Sterilized cotton pledgets, moistened with sterile saline, were applied if necessary to control the bleeding. After application of calcium hydroxide (Dycal, Dentsply, Milford, DE), cavities were sealed with amalgam (Dispersalloy, Kerr, Emeryville, CA) and covered with RZOE to prevent microleakage. Calcium hydroxide was used despite its known effects of the pulpal surface in order to achieve comparability

TABLE 1. Treatment Allocation

Treatments	No. of teeth per dog	Total teeth (5 dogs total)	Exposures	Exposure to oral contamination
Laser	1	5	2 mm	3 hr
Drill	1	5		
Laser	1	5	2 mm	72 hr
Drill	1	5		
Laser	1	5	5 mm	3 hr
Drill	1	5		
Laser	1	5	5 mm	72 hr
Drill	1	5		

TABLE 2. **Intraoperative, Clinical, and Radiographic Treatment Outcome**

Scores	Laser 2 mm 3 hr	Laser 2 mm 72 hr	Laser 5 mm 3 hr	Laser 5 mm 72 hr	Control 2 mm 3 hr	Control 2 mm 72 hr	Control 5 mm 3 hr	Control 5 mm 72 hr
Hemostasis—yes	5	5	5	5	5	3	3	1
Hemostasis—no	0	0	0	0	0	2	2	4
Clin: (−2)[a]	0	0	0	3	1	3	2	3
Clin: (−1)[b]	0	1	0	2	2	2	3	2
Clin: (0)[c]	5	4	5	0	2	0	0	0
Radiogr: (−2)[d]	0	0	0	4	2	3	2	4
Radiogr: (−1)[e]	0	1	0	1	1	2	3	1
Radiogr: (0)[f]	5	4	5	0	2	0	0	0

[a]Clinical presence of abscess formation, pus drainage, sinus tract.
[b]Periapical palpation suggests the development of a pathosis.
[c]Unchanged from pretreatment condition.
[d]Development of periapical pathosis indicated by an area of rarefaction or internal root resorption.
[e]Break in continuity of the lamina dura.
[f]Unchanged from pretreatment condition.

with conventional pulp treatments which usually employ this medicament.

Laser Device and Laser Parameters

A CO_2 laser (Duolase™), emitting at 9.3 μm, was used in the Superpulse, noncontact mode, at the following parameters: macropulse duration: 300 μs, spot size: 250 μm, average energy: 3.5 W, peak energy: 20 W, pulse repetition rate: ~500 Hz.

The parameters used were one of a series of laser configurations investigated within the framework of a comprehensive study, of which this is one subsection.

Evaluation of Treatment

At weekly intervals, treated teeth were monitored by the same blinded, prestandardized clinician.

Clinical Evaluation

Response to treatment was scored after visual and tactile examination as follows: −2: clinical presence of abscess formation, pus drainage, sinus tract; −1: periapical palpation suggests the development of a pathosis; 0: unchanged from pretreatment condition.

Radiographic Evaluation

Standardized periapical radiographs were scored as follows: −2: development of periapical pathosis indicated by an area of rarefaction or internal root resorption; −1: break in continuity of the lamina dura; 0: unchanged from pretreatment condition.

Statistics

The Chi-square and Fisher's exact test (2-tailed), as well as regression analysis, were performed.

RESULTS

Numerical scores for the treatment groups are depicted in Table 2.

Clinical and Radiographic Outcome

In the laser-treated teeth, immediate intraoperative hemostasis was achieved in 20/20 teeth with minimum postoperative clot formation. In the control teeth, hemostasis was problematic in 8/20 teeth with significant postoperative clot formation. Pressure from a cotton wool pledget soaked with sterile saline was required in order to achieve hemostasis.

Laser-treated group response. In the laser-treated group with 2 mm exposures and 3 hours contamination, 5/5 teeth remained clinically and radiographically healthy over 3 months. After 72 hours contamination, 4/5 teeth remained clinically, and radiographically healthy over 3 months. In the laser-treated group with 5 mm exposures and 3 hours contamination, 5/5 teeth remained clinically and radiographically healthy over 3 months. After 72 hours contamination, 0/5 teeth remained clinically and radiographically healthy over 3 months.

Control group response. In the control group with 2 mm exposures and 3 hours contamination, 2/5 teeth remained clinically and radiographically healthy over 3 months. After 72 hours

contamination, 0/5 teeth remained clinically and radiographically healthy over 3 months

Statistical Evaluation

Clinical and radiographic treatment outcome differed substantially between the laser-treated group and the control group. When assessed using the Chi-square test and Fisher's exact test (2-tail), the laser-treated group was associated with better overall posttreatment pulpal health than the control group ($P < 0.001$). A significantly greater number of pulps in the laser-treated group remained vital and radiographically healthy. Using regression analysis, duration of pulpal exposure to contamination was identified as primary determinant of treatment outcome within laser-treated and control groups ($P = 0.0018$). Exposure size did not significantly affect the treatment outcome for the laser group ($P < 0.0381$). In the control group, the exposure size was significant ($P < 0.002$).

DISCUSSION

Clinical and radiographic treatment outcome was better in the laser-treated group than in the control group. We attribute this result to the ability of the laser treatment at the parameters used to fulfill the preconditions for successful laser pulp surgery: good hemostasis, minimal postoperative clot formation, and minimal surgical trauma to underlying tissue. Other factors may include wound sterilization [12,22,23], reduced postoperative swelling, and oedema [12,13,20,24].

Immediate and effective intraoperative hemostasis was achieved in all laser-treated teeth. Subsequent postoperative clot formation was minimal. Good hemostasis is consistent with results of laser treatment published by other authors regarding blood vessels ≤ 5 mm in diameter (20,27). However, hemostasis was difficult to achieve in 8 of the 20 control teeth. Furthermore, substantial postoperative clot formation was observed. The poor treatment outcome in control teeth is in part attributed to the presence of an extrapulpal blood clot after pulpotomy, preventing direct contact of the calcium hydroxide, antibacterial capping agent, with the underlying pulp tissue (9,28).

The pulps left open to contamination from the oral environment for 72 hours demonstrated a low survival rate, regardless of the treatment methods used. These results are consistent with reports describing the development of severe inflammatory changes within the pulp tissues ~48 hours after the onset of contamination. A significantly worse than normal treatment outcome is expected when teeth are exposed to the oral environment for >48 hours prior to pulpotomy [29]. Moreover, the debris from the environment can further impede healing in the area by causing further pulpal inflammation.

Results of this investigation indicate that duration and extent of pulpal infection are more important in defining treatment outcome than exposure size. Several factors appear relevant when considering this observation: As we were unable to ascertain whether all compromised pulpal tissues were fully removed, inadequate elimination of pathological tissues may have played an important role, or extensive bacterial invasion and pulpal inflammatory response may have been determinants for the treatment outcome.

The observation that exposure size affected treatment outcome in the non-laser group only may be related to the laser's capacity for excision, surface bacterial elimination, and hemostasis, whereas hemostasis and adequate excision became increasingly more difficult to achieve in larger wounds after conventional surgical techniques.

Although this study was performed in mature, permanent teeth, localized laser pulp surgery may well produce better results in primary or immature permanent human teeth than in the mature dentition. Due to the reduced blood supply through the closed apices of permanent teeth, their capacity for recovery after insult is thought to be inferior to that of primary or immature permanent teeth [4]. A treatment modality that provides an alternative to formocresol pulpotomies is particularly desirable given the controversy over the safety of formocresol, in the light of its toxic, mutagenic, and carcinogenic effects [4]. Questions regarding the vitality of the apical pulp and the normalcy of the periapical tissues after the application of formocresol also have been raised [4].

In conclusion, this study demonstrated that localized laser pulp surgery can be a successful clinical tool. Further research is required to delineate limits and identify optimal laser parameters.

ACKNOWLEDGMENTS

Our thanks to Medical Optics (Carlsbad, CA) for the loan of their device.

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